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# THE GROWTH AND MANAGEMENT OF DOUGLAS FIR IN THE PACIFIC NORTHWEST.

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# CONTENTS.



# ILLUSTRATIONS.

# THE GROWTH AND MANAGEMENT OF DOUGLAS FIR IN THE PACIFIC NORTHWEST.

## INTRODUCTION.

Up to the present time, in logging operations in the Pacific Northwest, very little thought has been given to the future of the logged-off land. The seemingly inexhaustible supply of virgin timber, the resulting low valuation of stumpage, the small margin of profit in logging, and the fact that much of the land already cut over is cultivable, have all combined to develop a system of timberland management which prevents rather than promotes the establishing of a second crop. It is natural, almost inevitable, on account of market conditions, that logging should have tended to annihilate the forest. Timber has been regarded as an unrenewable resource, like coal, instead of as a crop which by proper management could be harvested periodically.

Now, however, the steady rise in the valuation of standing timber, the growing scarcity of very accessible bodies of timber, the broadening market for Northwestern lumber, the probability of reform in the taxation of timberland, and the better protection of forest land from fires, are all tending to bring on an era in which thought will be taken for the future of the land logged off, so that when the original forest is cut, measures will be taken to leave the land in a condition to develop a new forest to take the place of the one removed.

Over a large part of western Washington and Oregon which has been logged over, or is now being logged, there will be no second crop of timber. From the present outlook there is no indication that these lands will bring their owners any returns in forty, fifty, or one hundred years. They are nonproducing, and yet they are capable of yielding periodically large crops of timber, if given the right treatment. Much of this land is suited to no crop of value, except timber, and this it will produce as abundantly as any other land in the country. It is an economic misfortune that so much land of this productiveness has, through fire following logging without thought for the future, been made essentially nonproducing.

Timberland management which develops a new crop of timber when the original forest is cut off will not only be profitable to the owner,

but it will promote the prosperity of the community by keeping in productive condition all potential timberland, and by perpetuating the logging and lumber-manufacturing industries.

The purpose of this circular is to show how a new crop of timber can be started on logged-off land, what conditions are favorable to its development, what its rate of growth and yield will be, and what should be the probable cost of securing the second crop.

The most important timber tree in the Pacific Northwest is Douglas fir,[1] a tree which originally covered in forests of great density and almost absolute purity the greater part of the foothills and lower slopes of the Cascade Mountains and the Coast Range. In western Oregon it now comprises about 80 per cent of the standing timber, and in western Washington 50 per cent. The fact that Douglas fir is by far the most abundant and most important commercial tree of this region, and that it has a combination of many excellent qualities, focuses the discussion of the conservative management of timberland on the western foothills of the Cascade Mountains in Washington and Oregon to a discussion of the management of this single species.

## CHARACTERISTICS OF DOUGLAS FIR.

Douglas fir is a vigorous, hardy, rapid-growing tree, capable of thriving under a great variety of conditions; but it has certain characteristics, a study of which determines under what form of timberland management it can be reproduced most successfully after logging and what conditions are favorable or unfavorable to its best development.

### SOIL AND CLIMATIC REQUIREMENTS.

Douglas fir will grow under a very wide range of soil and climatic conditions, but it makes rapid growth only on fairly deep, well-watered soils, where there is at least 40 inches of rainfall a year and where the growing season is long. Its preference is for a fine loamy soil; on rocky, gravelly, or shallow soils, as well as on poorly drained, wet soils its growth is inferior. Provided that the soil is of the right character and depth, the tree seems to do as well, and possibly better, on slopes, however steep, than on level land.

[1] Douglas fir (*Pseudotsuga taxifolia*) has a number of common names by which it is known in the Pacific Northwest—Douglas fir, red fir, yellow fir, Douglas spruce, or simply fir. In commerce it is also called Oregon pine, red pine, Puget Sound pine, Washington fir, or British Columbia pine. Of all these names, Douglas fir, the one adopted by the Forest Service after a lumber census in which this name was used more than all other names combined, is the most satisfactory, being absolutely distinctive and covering various forms of the tree which are known by local names. The terms "red fir" and "yellow fir" are often used to distinguish between two fairly distinct forms of wood which this single species produces, depending upon the age of the tree and the conditions under which it has grown. The term "red fir" is applied to trees which are ordinarily immature and have rather coarse-grained and reddish-colored wood; the term "yellow fir" applies to trees which are of mature age and whose wood is fine grained, yellow in color, rather soft, and easily worked.

## DENSITY OF STAND.

The ability of a tree to endure shade, or in other words, its demand for light, decides how many trees will grow on an acre, and is therefore an important characteristic of a tree. Douglas fir is moderately dependent upon light, being able to endure more shade than some of its associates, but less than others, such as western hemlock and western red cedar. In order to remain alive after their first few years,

FIG. 1.—Part of a 45-year-old stand of Douglas fir near Crow, Oreg., which is occupying land formerly covered with nothing but brush, because of repeated fires set by Indians.

Douglas firs must receive direct top light, and with advancing age they become more exacting in this regard; trees which are overshadowed completely by their neighbors quickly die. This fact explains why this tree, in order to attain optimum development, should grow in even-aged stands, where all the trees are of about the same height and all receive direct top light. (Fig. 1.)

Douglas fir has to an unusual degree the ability to form dense stands, and this in part accounts for its immense yields per acre. Table 1 gives the number of trees of various sizes that are normally found in even-aged forests of several ages. At 20 years of age there are 990 trees to the acre, at 30 years, 580, and so on, decreasingly, until at 100 years there are about 115 to the acre. After this the number decreases more slowly.

TABLE 1.—*Average number of trees of various diameter classes in even-aged stands of Douglas fir, on quality 1 soils, western foothills of the Cascade Mountains, in Washington and Oregon.*

[Read from curves based on the measurement of 252.31 sample acres.]

| Diameter at breast height (inches). | Age of stand in years. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | | 30 | | 40 | | 50 | | 60 | | 70 | | 80 | |
| | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. |
| | Average number of trees per acre. | | | | | | | | | | | | | |
| 1–5 | 740 | 92 | 285 | 56.0 | 94 | 34.0 | 57 | 21.0 | 38 | 17.0 | 29 | 13.0 | 21 | 12.0 |
| 6–10 | 234 | 8 | 242 | 8.0 | 213 | 8.0 | 149 | 8.0 | 80 | 8.0 | 54 | 8.0 | 40 | 8.0 |
| 11–15 | 16 | ...... | 53 | .5 | 82 | 1.5 | 90 | 2.0 | 91 | 2.0 | 71 | 2.0 | 46 | 2.0 |
| 16–20 | ...... | ...... | ...... | ...... | 20 | .3 | 37 | .4 | 43 | .6 | 34 | .7 | 27 | .7 |
| 21–25 | ...... | ...... | ...... | ...... | 1 | ...... | 7 | ...... | 12 | .2 | 16 | .3 | 21 | .3 |
| 26–30 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1 | ...... | 4 | ...... | 8 | ...... |
| 31–35 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3 | ...... |
| 36–40 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1 | ...... |
| Total | 990 | 100 | 580 | 64.5 | 410 | 43.8 | 340 | 31.4 | 265 | 27.8 | 208 | 24.0 | 167 | 23.0 |

| Diameter at breast-height (inches). | Age of stand in years. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 90 | | 100 | | 110 | | 120 | | 130 | | 140 | |
| | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. | Douglas fir, etc. | Others. |
| | Average number of trees per acre. | | | | | | | | | | | |
| 1–5 | 18 | 12.0 | 17.00 | 12.0 | 16.00 | 13.0 | 13.00 | 13.0 | 11.00 | 13.0 | 8.00 | 12.0 |
| 6–10 | 30 | 8.0 | 23.00 | 8.0 | 19.00 | 8.0 | 16.00 | 8.0 | 11.00 | 8.0 | 8.00 | 8.0 |
| 11–15 | 26 | 2.5 | 19.00 | 3.0 | 15.00 | 3.0 | 12.00 | 3.0 | 8.00 | 2.5 | 5.00 | 1.5 |
| 16–20 | 19 | .8 | 14.00 | .8 | 11.00 | .8 | 8.00 | .8 | 4.00 | .7 | 2.00 | .6 |
| 21–25 | 20 | .4 | 17.00 | .4 | 14.00 | .3 | 14.00 | .2 | 15.00 | .2 | 16.00 | .1 |
| 26–30 | 14 | .2 | 13.00 | .3 | 12.00 | .3 | 13.00 | .2 | 16.00 | .1 | 18.00 | .1 |
| 31–35 | 7 | ...... | 8.00 | .3 | 8.00 | .3 | 10.00 | .2 | 15.00 | .1 | 19.00 | .1 |
| 36–40 | 3 | ...... | 4.00 | .1 | 4.00 | .1 | 5.00 | .1 | 8.00 | .1 | 10.00 | .1 |
| 41–45 | ...... | ...... | .51 | ...... | .86 | ...... | 1.27 | ...... | 1.77 | ...... | 2.13 | ...... |
| 46–50 | ...... | ...... | ...... | ...... | ...... | ...... | .14 | ...... | .22 | ...... | .33 | ...... |
| Total | 137 | 23.9 | 115.51 | 24.9 | 99.86 | 25.8 | 92.41 | 25.5 | 89.99 | 24.7 | 88.46 | 22.5 |

NOTE.—In addition there is on the average 0.67 veteran Douglas fir per acre for the plots measured which belongs to a distinctly older generation than the main stand. The column headed "Douglas fir, etc.," includes all Douglas fir, western hemlock, grand fir, and Sitka spruce; over 95 per cent of the trees are Douglas fir. The column headed "Others" includes all western red cedar, western yew, and hardwoods.

The density of the stand has a material bearing on the quality of the timber produced. Trees which have developed in dense stands

are more cylindrical, their limbs are smaller, and they shed their dead branches earlier than those which have grown in the open. In a well-stocked stand the shedding of the dead limbs begins when the trees are about 45 years old; at an age of 80 years the stems of the trees should be smooth and clear of dead stubs well up to where the live branches begin. That is to say, even in dense stands Douglas fir will not produce any clear lumber until it is 50 or 60 years old (15 to 17 inches in diameter on the average); in open stands not until it is much older. In even-aged stands of sufficient density after 75 or 85 years all the lumber grown on the lower part of the trees should be free of knots.

### SUSCEPTIBILITY TO INJURY.

Douglas fir is a tree which up to the time of its maturity is remarkably free from all sorts of diseases and injuries. The majority of the defects which are found in Douglas fir stands are the result of fire.

#### FIRE.

Fire damage is of two kinds, (*a*) direct and (*b*) indirect; both cause an enormous economic loss, but of the two, the latter is of greater commercial importance, though its method of working is so insidious as usually to be unobserved.

(*a*) *Direct damage.*—The direct damage from forest fires may be classified under two headings, that caused by crown fires and that caused by surface fires. A crown or top fire sweeps through the foliage of the trees, burning all their finer parts in an intensely fierce heat and ordinarily killing all the trees in its path. Crown fires are the outgrowth of surface fires, and, contradictory as it may seem, they usually occur not where the trees stand most densely, but where the stand is fully mature and therefore somewhat broken, allowing a rank underbrush to develop and become in the summer season very dry and ready food for surface fires. If surface fires, therefore, were prevented, there would be no crown fires. The damage done by crown fires is conspicuous and is universally deplored. Vast areas of Douglas fir have been killed by crown fires, since its habit of growth renders it extremely liable to them.

Although Douglas fir forests are very liable to be burned over by surface fires, because in dry seasons the duff and underbrush becomes exceedingly inflammable, yet the season in which surface fires will run in these woods is short. This tree has a heavy, fire-resistant bark, and after about 25 years of age a forest of this species is not apt to be killed outright by a surface fire. Nevertheless, some trees in the stand above this age, which are seemingly immune from fire, have a point of weakness in their bark by which fire gains access to

the pitchy butt, which is quickly eaten out, and the trees are either killed outright or made easy prey for the next severe wind or surface fire. While this form of injury is not conspicuous to the casual observer, owing to the fact that only an occasional tree is so killed, nevertheless the loss in the aggregate is enormous and constitutes the greatest direct damage of surface fires. In stands under about 25 years of age, where the bark has not become thick enough to render the tree immune from heat, large patches of young trees are killed outright. The damage to young stands, even though their market value is at the time nothing, is nevertheless very real, for years of growth during the period of most rapid growth are lost.

(*b*) *Indirect damage.*—The indirect damage done by forest fires is due to the injury caused by the fires to trees which survive the fire and live to maturity. When a young stand, for example, one about 15 or 25 years old, is burned over by a light surface fire, often only part of the trees are killed and enough survive to form eventually a full stand, but these survivors are very apt to be fire-scarred. These scars are the entering places for fungi which cause butt rot. The rot in turn does not kill the tree, but gradually spreads and renders useless a portion of the lower part of it. The scar is grown over in time and the rot is hidden, but the decay continues to spread. It is safe to say that the great majority of butt rot in immature stands of Douglas fir is due to surface fires, and this indirect result of forest fires is alone a sufficient reason for their prevention. Pitch seams are one of the most serious defects in Douglas fir lumber, and these are often caused by surface fires.

Repeated forest fires exert an unfavorable influence on the soil by burning the ground cover and the vegetable material that it contains. The needles and twigs that cover the ground retard the run-off of the rainfall and assist the soil in absorbing and retaining moisture. When this material is consumed the soil is rendered less favorable to the reception of moisture, its nutritive value is decreased, and consequently the growth of the forest is impeded.

Another harmful effect of surface fires in young stands is the destruction of the uniformity of the forest, through the killing out of patches of trees here and there, opening up the stands in an abnormal, uneven way so that the quality of the mature trees in a stand which has been early scourged by fire is inferior to that in one which has not suffered from fires during its development.

## FUNGI.

The amount of decay found in living Douglas firs up to the time they are 150 years old or so is very small, but in mature and overripe timber there is a great deal of defect due to decay. All decay in trees

is induced by parasitic fungi which enter the tree from the exterior and grow and feed on the wood, thereby causing it to "decay." Douglas fir trees apparently resist infection from fungi well until they become mature, when, because of the opening up of the stand, breakage, and scars due to the action of the elements and of fire and insects, and also because with advancing age their resistant power becomes less, they offer entrances to fungi.

### INSECTS.

Scores of different kinds of insects live on the wood, bark, foliage, and cones of Douglas fir, but only a very few species are known to destroy living trees. One of these, the Douglas fir beetle (*Dendroctonus pseudotsugæ*), is a serious enemy of the tree.[1]

### REPRODUCTION.

Douglas fir is a good seed producer, and bears enormous crops of cones at intervals of from two to four years. The seed is light and winged and is scattered widely by the wind during a period of several months, beginning early in September, when the cones first open. While seed may under unusual circumstances be disseminated a half mile, the maximum distance to which satisfactory reproduction can be relied upon under average conditions is about 350 feet, or a distance equal to nearly twice the height of the seed tree. (Fig. 2.)

Douglas fir seed germinates in almost any situation that the seed chances to fall into, provided there is sufficient moisture, but it is only the seedlings whose roots quickly come in contact with mineral soil and which receive direct light that survive. This fact makes Douglas fir reproduction in western Washington and Oregon dependent to a large degree on fire. On cut-over areas on which the débris has not been burned there is usually such a layer of branches, needles, and partly decayed vegetable material that seedlings can not start vigorously, but when fire has removed this layer and exposed the mineral soil reproduction has a chance.

On cut-over areas and burns in the Pacific Northwest a tangle of bushes, ferns, and grasses springs up and forms a thicket which is detrimental to Douglas fir reproduction by preventing the seed from reaching the mineral seed bed, by forming a canopy which shades the seedlings, and by acting as a physical barrier to their growth. In brushy regions, therefore, it is important that there be a good seed year, and that reproduction become established as soon as possible after the area is cut or burned over, so that before the brush becomes dense and tall the seedlings will reach such size that they can not be

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[1] A full account of this beetle and of the methods for controlling it has been published by the Bureau of Entomology.

damaged by it. If the brush has two or three years' start over the tree reproduction, it is almost impossible for Douglas fir seedlings to become established in competition with it. Repeated fires on logged-off land have the effect of increasing the density of the brush, and consequently make less favorable the conditions for Douglas fir reproduction.

Fig. 2.—A hillside near Lowell, Oreg., which a half century ago was "prairie" with only occasional scattered trees upon it. Now it is covered with a dense 49-year-old forest of trees 5 to 25 inches in diameter.

While only about 2,000 or 3,000 good, vigorous seedlings per acre are necessary for the formation of a well developed and fully stocked mature stand, yet over 100,000 are commonly found on an acre. Logged-off lands and burns which are restocking usually have at least 10,000 seedlings per acre ten or fifteen years after the original stand is removed.

## RATE OF GROWTH.[1]

In western Washington and Oregon Douglas fir is an extremely rapid growing tree, and upon this fact largely rests the profitableness of growing crops of this tree on land from which the original forest is now being removed. Table 2 shows the average rate of diameter and height growth of Douglas fir in this region. It is seen that in its second decade the average tree attains its maximum rate of both diameter and height growth and thereafter the rate decreases, but this is quite a different thing from volume growth (see Table 3), the

Fig. 3.—Twenty-four-year-old stand of Douglas fir on edge of slashing. The height growth of each year is shown by the whorls of branches.

rate of which keeps on increasing up to 140 years, the limit of the table, and perhaps longer. It is not unusual for trees from 10 to 30 years old to add 4 feet to their height and three-fourths of an inch to their diameter in one year. The greater part of a tree's height

[1] The data for the tables in this circular were collected in a number of typical localities, all west of the Cascade Mountains and east of the Coast Range, from near the Canadian line in Washington southward to Cottage Grove, Oreg., in stands which were approximately even-aged and consisted, at least to the extent of 75 per cent, of Douglas fir, and were growing on the better class of soils, assuming that all true forest soils were graded into two classes. It must be remembered, therefore, that the growth and yield tables of this circular are local in their application and can be used safely only with even-aged, moderately pure Douglas fir stands on the better forest soils of the western foothills of the Cascade Mountains.

growth is made during its first 75 years; at 150 years the average tree has practically reached its maximum height. Diameter growth is sustained much longer, provided the tree has ample growing space. (Fig. 3.)

TABLE 2.—*Average diameter at breast-height, average total height, and average annual diameter and height growth of Douglas fir trees of various ages.*

[Diameters based on 1,807 stump analyses. Heights based on 1,648 trees.]

| Age. | Average diameter at breast-height. | Average annual diameter growth in each decade. | Average total height. | Average annual height growth in each decade. |
|---|---|---|---|---|
| *Years.* | *Inches.* | *Inch.* | *Feet.* | *Feet.* |
| 10 | 1.5 | .......... | 13.0 | .......... |
| 15 | 3.6 | 0.43 | 26.0 | 2.58 |
| 20 | 5.8 | .......... | 38.8 | .......... |
| 25 | 7.7 | .38 | 51.0 | 2.47 |
| 30 | 9.6 | .......... | 63.5 | .......... |
| 35 | 11.0 | .27 | 76.0 | 2.35 |
| 40 | 12.3 | .......... | 87.0 | .......... |
| 45 | 13.7 | .27 | 95.0 | 1.55 |
| 50 | 15.0 | .......... | 102.5 | .......... |
| 55 | 16.2 | .23 | 109.5 | 1.25 |
| 60 | 17.3 | .......... | 115.0 | .......... |
| 65 | 18.4 | .22 | 120.5 | 1.04 |
| 70 | 19.5 | .......... | 125.4 | .......... |
| 75 | 20.4 | .17 | 130.3 | .98 |
| 80 | 21.2 | .......... | 135.2 | .......... |
| 85 | 22.0 | .15 | 139.9 | .94 |
| 90 | 22.7 | .......... | 144.6 | .......... |
| 95 | 23.4 | .14 | 149.4 | .95 |
| 100 | 24.1 | .......... | 154.1 | .......... |
| 105 | 24.8 | .14 | 158.8 | .94 |
| 110 | 25.5 | .......... | 163.5 | .......... |
| 115 | 26.2 | .13 | 168.2 | .95 |
| 120 | 26.8 | .......... | 173.0 | .......... |
| 125 | 27.5 | .13 | 177.8 | .95 |
| 130 | 28.1 | .......... | 182.5 | .......... |
| 135 | 28.8 | .13 | 187.2 | .95 |
| 140 | 29.4 | .......... | 192.0 | .......... |

TABLE 3.—*Average volume and average annual volume growth of Douglas fir trees of various ages, expressed in cubic feet and in board feet by the Scribner Decimal C Rule.*

| Age. | Volume. | Annual growth. | Volume. | Annual growth. |
|---|---|---|---|---|
| *Years.* | *Cubic feet.* | *Cubic feet.* | *Board feet.* | *Board feet.* |
| 10 | 0.1 | 0.01 | .......... | .......... |
| 20 | 3.1 | .30 | .......... | .......... |
| 30 | 13.3 | 1.02 | .......... | .......... |
| 40 | 28.0 | 1.47 | 118 | .......... |
| 50 | 48.5 | 2.05 | 238 | 12.0 |
| 60 | 70.0 | 2.15 | 386 | 14.8 |
| 70 | 93.3 | 2.33 | 552 | 16.6 |
| 80 | 117.0 | 2.37 | 699 | 14.7 |
| 90 | 138.2 | 2.12 | 842 | 14.3 |
| 100 | 160.3 | 2.21 | 981 | 13.9 |
| 110 | 186.4 | 2.61 | 1,137 | 15.6 |
| 120 | 216.8 | 3.04 | 1,295 | 15.8 |
| 130 | 249.1 | 3.23 | 1,465 | 17.0 |
| 140 | 288.8 | 3.97 | 1,655 | 19.0 |

Many factors influence the rate of growth, which varies with every locality and in fact with each individual tree. The most rapid growth is made where the soil is deep, loamy, fresh, and well drained, where the growing season is long, and the stand fully stocked, but not overcrowded, for overcrowding causes the growth to stagnate.

## MANAGEMENT OF SECOND-GROWTH STANDS.

The preceding discussion of the characteristics of Douglas fir has shown that it is a tree which is especially adapted to be grown in stands which are approximately even-aged and consist principally of this single species. This is a form of forest in which it ordinarily occurs in the virgin woods, and it is the form of forest which is most easily obtained by the natural reforestation of cut-over lands.

Fortunately for the future of the forests of the Pacific Northwest, Douglas fir is a vigorous tree, which in this region produces, without much assistance and often against severe obstacles, excellent, even-aged, almost pure, second-growth stands. The thousands of acres of magnificent young stands on cut-over lands and burns in this region testify to the fact that it is easy to obtain a vigorous, rapid-growing second growth of Douglas fir after logging. It is surprising that so much good young growth has developed under unfavorable circumstances, in spite of repeated fires and the haphazard, infrequent occurrence of seed trees. The obtaining of reproduction of this species after logging is a simple problem, therefore, and does not entail any decided modification of present logging methods. The stands developed under systematic management and protection, moreover, should be superior in quality and perhaps in yield to those in the virgin woods. The virgin stands have been damaged by fire, which can be prevented under proper management; many of them are not fully stocked, and therefore produce inferior timber; and they are often uneven-aged. None of these conditions will prevail under systematic management. There is reason to believe, therefore, that the stands of the future can be made to produce more and better timber to the acre than have the average forests of the past.

The timberland operator who desires to secure succeeding crops of timber to take the place of the stands removed, while he readily concedes that it is possible to obtain another crop of timber on cut-over land, that its growth would be fully as rapid as the original stand, and that its quality would be equal to that of virgin stands of the same age, nevertheless has several practical questions to ask before he decides whether he can afford to hold his logged-off lands for a second crop—that is, to practice forestry or not:

1. What steps are necessary to secure a second crop of timber on cut-over land?
2. What will the returns be from the second crop?
3. What will it cost to hold logged-off land and grow a second crop of timber?

### PROVISIONS FOR A SECOND CROP.

The handling of a logging operation in Douglas fir timber so as to obtain a second crop to succeed the virgin forest is not a complicated

process and can be practiced with success simply by the exercise of intelligent woods supervision and the expenditure of some labor in brush burning and fire protection. It resolves itself into three operations, none of which requires much modification of the present so-called "destructive" methods of logging:

I. Clean cutting the area (except that some provision must be made for seed trees).

II. Clearing the area of débris by fire for the purpose of preparing a seed bed.

III. Protecting the area from subsequent fires.

(I) In most logging operations at the present time in western Washington and Oregon the area is cut clean and all the merchantable material is removed. This is the first step in the practice of forestry, but to get reproduction seed is necessary. Sometimes occasional trees or groups of trees of seed-producing size have to be left here and there because they are defective or inaccessible. In other places the cutting area is bordered by timber which is not to be cut for some years because the land is under other ownership or the timber on it is not merchantable. In such cases, where the cut-over area is by force of circumstances supplied with seed trees, no special provision for seeding up the area is necessary, since it will be supplied with seed from the unmerchantable trees left standing upon it, or from the adjoining green timber. But where in ordinary logging practice the cut-over area would be left without sufficient seed trees, some special provision for seeding up the area should be made by the logger. This can be done in either of two ways:

(*a*) Leaving seed trees wherever they are needed. Whenever the cutting is so extensive that an area would be left without sufficient trees of seed-producing size and form, special provision should be made to leave the necessary number of seed trees. This can best be done by selecting, just ahead of the falling crews, the trees that should be left, and conspicuously marking them. Trees should be left which are not sickly, suppressed, or leaning, and which are large and strong enough not to be broken off or stripped of limbs by the falling of their neighbors. It is by no means necessary to select trees of the greatest merchantable value; those forked or otherwise misshapen are suitable, provided they are not dying or unthrifty. Often trees of this class are logged and even sawed up at an actual loss, since it costs more to convert them into lumber than the value of the merchantable material they yield. Woods supervision, therefore, which will prevent the cutting of trees not worth logging will serve the double purpose of furnishing seed trees and of cheapening the logging. The leaving of trees which have a marketable value to seed up a cut-over area represents an investment equal to their merchantable value, unless they can be subsequently logged, which is not probable.

No fixed rule can be laid down as to the spacing of the seed trees, because seed dissemination is so dependent upon local topography, winds, and the character of the seed trees. On level land, as a general rule, in order to be sure of obtaining reproduction, no part of a cut-over area should be farther than 350 feet from a seed-bearing tree; on slopes where the seed trees occupy commanding positions, the distance can safely be greater. A seed tree to each 2 or 3 acres should be sufficient, provided it remains alive and standing for at least eight years after the area is logged off, or until several crops of seed have been disseminated.

When there is danger that solitary seed trees will be windthrown, or there is a clayey, wet soil, the seed trees should be left in groups, so that they may mutually support each other. The groups, like the solitary seed trees, should be located in commanding positions, from which their seed will be disseminated far and wide; yet they should not be in locations so exposed that they are liable to damage from storms.

(*b*) The other method of regenerating cut-over areas is to sow Douglas fir seed artificially. This method has not been used to any extent up to the present time with Douglas fir, but experiments so far made indicate that the results will be satisfactory, and that in certain cases it will actually mean the investment of less money than leaving merchantable trees for seed.

(II) As has been said, Douglas fir needs a mineral seed bed, clear of débris. To obtain this, logging areas should be burned over. Most cut-over areas are now burned over by accident, but one fire never consumes all the branches, tops, and cull logs. A year or two later or perhaps ten years later fires will again run through this débris and kill all young growth that has started in the meantime. It is essential that cut-over areas should be burned over under supervision immediately after they are logged, and that the fire should be as thorough as possible. When a cut-over area, on which seed trees have been left, is burned over, the first consideration must be to protect these seed trees and to prevent the fire from running into the green woods. To attain this, the heaviest dry brush should be moved back a few rods from the seed trees and the borders of the green woods, and back fires should be set. To keep the fire under control, as small a block should be burned at one time as the topography and method of logging will allow. In order that the fire may burn up all the débris completely, the brush should be as dry before being fired as is consistent with safety to the seed trees and adjoining timber. Either fall or spring is suitable for broadcast burning, except on areas where there are many dry stubs which might hold fire for weeks, if fired in the spring, and spread it during the summer dry season.

(III) After one thorough fire has gone over the area and consumed the finer débris, a system of fire protection must be installed to keep the area free from fires thereafter. The fire protection must be perfect, for seedlings during their first few years are quickly killed by the lightest ground fire. Reproduction has its best chance if it starts immediately after the first brush burning; hence a second fire that kills the first crop of seedlings lessens this chance of successful growth.

Already much of the private land west of the Cascades in Washington and Oregon is protected from fire, and it is being demonstrated that it is not an impossible task to keep fire out of the woods of this region. Cut-over lands are not protected to the same extent as the old timber is; yet in the long run it is just as important that fire be kept out of cut-over lands covered only with little Douglas fir "brush" as that it be kept out of the marketable timber.

## YIELDS.

Table 4 gives in board feet by the Scribner Decimal C rule and in cubic feet[1] the yield per acre that can be expected from pure, even-aged stands of Douglas fir of various ages, and shows that a piece of land cut over this year and properly managed will yield 60 years from now 41,000 feet of saw logs to the acre; 100 years hence it will have 79,800 feet; that is, on the average 800 feet of lumber will grow on that acre every year. Expressed in cubic feet the yield is also surprisingly large. Between 40 and 60 years of age, a stand of Douglas fir produces on each acre annually over 200 cubic feet of wood. (Fig. 4.)

TABLE 4.—*Yield for even-aged stands of Douglas fir on quality 1 soils, western foothills of the Cascade Mountains in Washington and Oregon, read from curves.*

[Based on $252\frac{5}{16}$ acres (361 sample plots).]

| Age. | Number of trees per acre. | Total basal area. | Diameter of average tree. | Height of average tree. | Yield per acre. | Average annual growth per acre in each decade. | Yield per acre. | Average annual growth per acre in each decade. |
|---|---|---|---|---|---|---|---|---|
| *Years.* | | *Sq. ft.* | *Inches.* | *Feet.* | *Cu. ft.* | *Cu. ft.* | *Ft. B. M.* | *Ft. B. M.* |
| 10 | | | | | 1,000 | | | |
| 20 | 990 | 116 | 4.6 | 32.0 | 2,150 | 115 | | |
| 30 | 580 | 149 | 6.9 | 46.0 | 3,550 | 140 | | |
| 40 | 410 | 177 | 8.9 | 59.0 | 5,400 | 185 | 12,400 | |
| 50 | 340 | 199 | 10.4 | 69.5 | 7,550 | 215 | 28,000 | 1,560 |
| 60 | 265 | 218 | 12.3 | 82.0 | 9,650 | 210 | 41,000 | 1,300 |
| 70 | 208 | 234 | 14.4 | 95.0 | 11,500 | 185 | 51,700 | 1,070 |
| 80 | 167 | 247 | 16.5 | 107.5 | 13,100 | 160 | 61,100 | 940 |
| 90 | 137 | 261 | 18.7 | 120.5 | 14,400 | 130 | 70,300 | 920 |
| 100 | 115 | 275 | 20.9 | 134.5 | 15,600 | 120 | 79,800 | 950 |
| 110 | 100 | 288 | 23.0 | 147.0 | 16,750 | 115 | 90,300 | 1,050 |
| 120 | 92 | 301 | 24.5 | 156.5 | 17,800 | 105 | 101,500 | 1,120 |
| 130 | 90 | 312 | 25.2 | 161.0 | 18,850 | 105 | 113,000 | 1,150 |
| 140 | 88 | 323 | 25.9 | 166.0 | 19,900 | 105 | 122,600 | 960 |

NOTE.—Including only Douglas fir, western hemlock, grand fir, and Sitka spruce; over 95 per cent of the trees are Douglas fir.

[1] The yield in cubic feet includes the contents of the whole stem of all the trees; that in board feet includes only the merchantable contents of trees 12 inches and more in diameter at breastheight, taken to a top diameter of 8 inches inside the bark.

Table 5 shows the yield by very close utilization of stands from 30 to 70 years old of all trees 7 inches or more in diameter, when the small trees and tops are converted into mining timber, the trees of tie size are converted into railroad ties, and larger sizes utilized for saw timber. This intensive form of utilization illustrates the large yield that is possible from comparatively young timber, which, in regions where there is any market for small material, means a large money value.

TABLE 5.—*Yield table, supplementary to Table 4, for even-aged stands of Douglas fir between 30 and 70 years old on quality 1 soils, western foothills of the Cascade Mountains in Washington and Oregon, showing yield per acre of all trees 7 inches or more in diameter, those between 7 and 19 inches being converted into hewed railroad ties and round mining timber, and those above 19 inches into saw timber.*

[Read from curves.]

| Age. | Mining timber. | Railroad ties. | Saw-timber. |
|---|---|---|---|
| *Years.* | *Lin. ft.* | *Number.* | *Board feet.* |
| 30 | 6,900 | 105 | ........... |
| 40 | 8,000 | 255 | 600 |
| 50 | 7,900 | 390 | 5,600 |
| 60 | 7,200 | 500 | 16,000 |
| 70 | 5,600 | 440 | 30,400 |

In calculating returns for many years in the future, as it is necessary to do in considering forest crops, many unknown quantities enter in which can only be roughly estimated at the present time. The following calculations, therefore, aim only to be approximations and introduce several assumptions, but they err, if at all, on the side of conservatism.

First, what will be the value of crops started now in 40, 50, 60, or 100 years? It is assumed that the yield is equivalent to that given in Table 4, and that all the material is classed as saw timber, which will be worth $5 per thousand on the stump 40 years hence, and go up in price $0.50 every decade thereafter—a very conservative estimate of the certain rise in the price of stumpage. With these assumptions, Table 6, column I, shows that in 40 years the gross value of the crop would be $62; in 50 years it would be $154; and at 100 years, $638. These figures are astonishingly large when compared with present values, but in the light of prices in other parts of the country and considering the rapid rise of values in this region they are not unreasonably high. The figures in this column do not include the receipts from cord wood obtainable in addition to the saw timber of the final crop or the returns from thinnings which can be made before the final crop is harvested. These are very considerable additional sources of revenue.

TABLE 6.—*Probable returns, expenses, and profit in growing future crops of Douglas fir.*

| Age. | Returns. | | Expenses. | | | | | Profit or loss. | |
|---|---|---|---|---|---|---|---|---|---|
| | Based on Table 4. | Based on Table 5. | Sum of initial investment and annual protection with compound interest at 4 per cent. | Tax A. | Tax B. | Total with tax A. | Total with tax B. | With tax A (Column I, minus Column VI). | With tax B (Column I, minus Column VII). |
| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. |
| *Years.* | | | | | | | | | |
| 30 | ........ | $43 | $10.91 | $5.05 | $4.21 | $15.96 | $15.12 | ............ | ......... |
| 40 | $62 | 88 | 16.75 | 8.55 | 7.49 | 25.30 | 24.24 | $36.70 | $37.76 |
| 50 | 154 | 157 | 25.40 | 13.74 | 12.34 | 39.14 | 37.74 | 114.86 | 116.26 |
| 60 | 246 | 256 | 38.20 | 28.41 | 20.07 | 66.61 | 58.27 | 179.39 | 187.73 |
| 70 | 336 | 352 | 57.14 | 53.87 | 31.51 | 111.01 | 88.65 | 224.99 | 247.35 |
| 80 | 428 | ....... | 90.19 | 94.43 | 48.45 | 184.62 | 138.64 | 243.38 | 289.36 |
| 90 | 527 | ....... | 126.70 | 157.55 | 76.03 | 284.25 | 202.73 | 242.75 | 324.27 |
| 100 | 638 | ....... | 188.14 | 253.38 | 116.87 | 441.52 | 305.01 | 196.48 | 332.99 |
| 110 | 768 | ....... | 279.10 | 398.10 | 182.00 | 677.20 | 461.10 | 90.80 | 306.90 |
| 120 | 913 | ....... | 413.73 | 615.20 | 278.41 | 1,028.93 | 692.14 | − 115.93 | 220.86 |
| 130 | 1,073 | ....... | 613.03 | 939.72 | 383.27 | 1,552.75 | 996.30 | − 479.75 | 76.70 |
| 140 | 1,226 | ....... | 908.03 | 1,423.52 | 632.36 | 2,331.55 | 1,540.39 | −1,105.55 | −314.39 |

Table 6 also gives (in column II) the probable returns from stands from 30 to 70 years old, where all the material above 7 inches in diameter is usable and the yield is equivalent to that in Table 5. Mining timber, it is estimated, will be worth 0.5 cent per linear foot 30 years hence and go up 0.25 cent every decade thereafter; ties, according to the estimate, will be worth 8 cents apiece in 30 years and go up 2 cents every decade, and saw timber will be worth $5 per thousand feet 40 years hence and go up 50 cents each decade thereafter. This close utilization will naturally bring in a higher gross revenue than would be the case if only trees over 12 inches in diameter were used.

The fact that Douglas fir timber does not reach marketable size, even with the most intensive utilization, until about 40 years old should not deter timberland owners from raising a second crop of Douglas fir on their cut-over lands. There is every reason to believe that before many years favorably located bodies of young Douglas fir will have a market value, even though the trees are still too small to be usable, and the value of such stands will be equal to the cost of producing them. This fact should be an encouragement to those who hesitate to make the investment of starting reproduction on cut-over land, protecting it, and paying taxes on it because they fear that it would be impossible for them to dispose of this land profitably until it yields saw logs or other material.

## COSTS.

The cost of practicing forestry in the Pacific Northwest can be estimated with a fair degree of accuracy, though it will not be constant in all localities and is influenced by many variable factors.

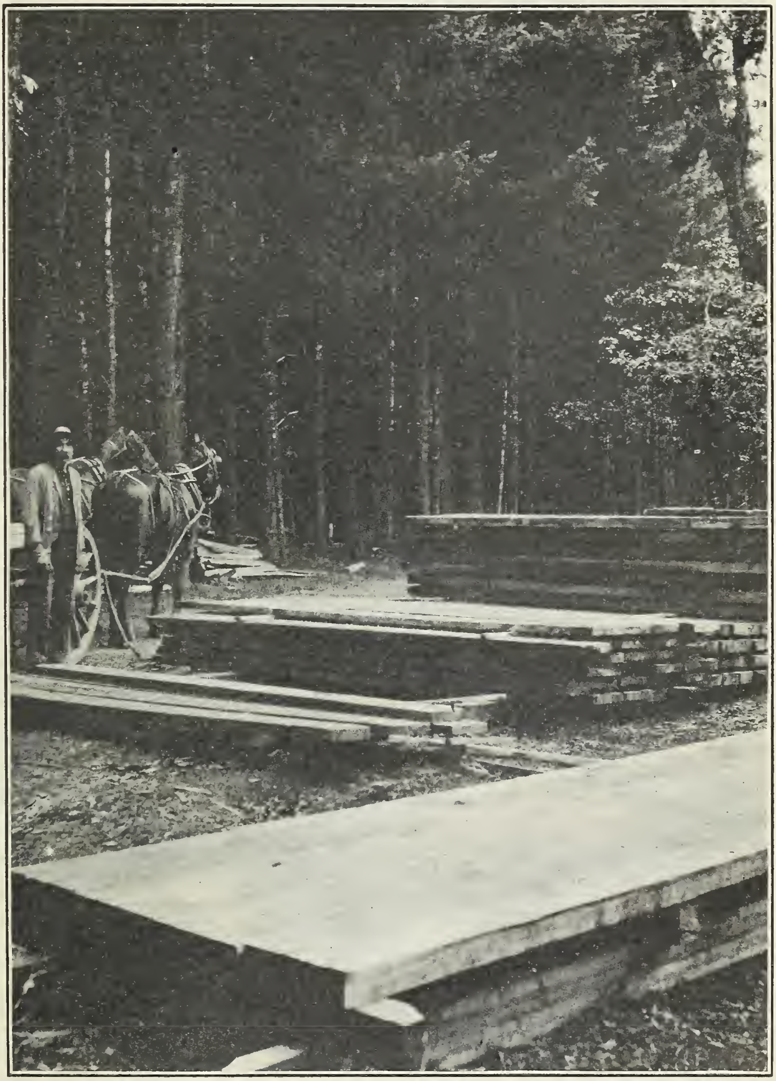

FIG. 4.—Lumber sawed from 45-year-old Douglas fir timber adjacent to that in the background.

There are four elements of expense in holding the cut-over land and promoting and caring for the second crop above what it would be if the land was abandoned after it was logged:

(1) Value of merchantable seed trees left to seed up the area and regarded as not utilizable later, $1.50 per acre, with compound interest thereon at 4 per cent. This is assuming that one marketable seed tree, containing about 2,000 feet, is left to each 2½ acres.

(2) Cost of burning the débris after logging and the protection of the seed trees at that time, $1 per acre, with compound interest thereon at 4 per cent.

(3) Fire protection, at 5 cents an acre per annum, with compound interest thereon at 4 per cent.

(4) Taxes, with compound interest thereon at 4 per cent.

If merchantable trees do not have to be left on the logging areas, no capital is tied up in seed trees; likewise if the seed trees will be usable at the end of the next rotation, and therefore a source of revenue, this first expense is neglible. The figures for the cost of burning over the logged-off land are liberal. An estimate of 5 cents an acre annually for fire protection is large, but the expenditure of so great a sum will eliminate the risk of loss to the investor that might exist if the expense for fire protection were made lower. In column III of Table 6 these first three expenses—seed trees, brush burning, and fire protection—are grouped together. Taxes are considered separately. Two forms of taxation are considered and the accrued cost of each calculated for various periods with compound interest at 4 per cent. Each system is representative of the form of taxation of timberlands in effect now in some counties of western Washington and Oregon in fairly accessible localities. The two methods will be designated A and B.

In tax system A the assessment is levied according to an estimate of the merchantable saw timber. Cut-over land on which Douglas fir reproduction is starting is taxed as cut-over land valued at $3 an acre for the first 50 years after being logged; thereafter it would be taxed according to a fairly close cruise and recruised every 10 years. It is assumed to have the amount given in the yield table (Table 4). The assessed value is 80 cents per thousand feet (which is low) and the combined tax rate 30 mills.

In tax system B the assessment is levied according to the actual value of the land and timber. In this computation the land for the first 30 years after it is logged off is valued at $2.50 per acre, the next 20 years at $3.50, from 50 to 80 years at $5, from 80 to 100 years at $12, beyond 100 years at $25 per acre. The combined tax rate is 30 mills.

As Table 6 shows, taxes are by far the greatest expense in growing a second crop. Their accrued amount, with interest, according to Table 6, is so large that it is impossible for an owner to hold timberland for any great length of time and make any profit. In 110 years

at the present rate of taxation an owner would pay (with 4 per cent interest) by tax system A $398 or by tax system B $182, while 110-year-old timber is worth at the present best prices only about $175 an acre. This means that the system of taxing timberland must be reformed before private owners can go into intensive practice of forestry on their cut-over lands with the assurance that they will make a reasonable profit. If a decided rise in the value of stumpage is assumed, as in Table 6, there is a profit in growing a second crop even with the present rate of taxation; without assuming a rise in the value of stumpage, there is no profit. Under the system now in force both the land and the value of the crop on the land are taxed annually, a form of taxation practiced with no agricultural crop, and yet the timberland owner gets no adequate protection from the State for his property, either from fire or theft.

## PROFITS.

It is somewhat speculative to predict what the profits from practicing forestry on Douglas fir timberland will be in the next 50 or 100 years, but a comparison of the returns and expenses, based on the assumptions explained in the preceding pages, all of which are conservative, shows most interestingly the probable net profit (or loss). These figures are given in columns VIII and IX of Table 6, and they show a steadily increasing profit up to an age of 80 years by tax system A, and 100 years by tax system B, amounting at those periods to $243 and $333 per acre, respectively.

Accordingly, the financial profit is greatest if the timber is cut when it reaches an age of 80 or 100 years, which may seem a very short rotation when it is considered that the majority of the timber now being logged in western Washington and Oregon is upward of 200 years old. The depletion of the supply of standing timber in the country, however, makes it certain that future generations will be very ready to use timber much smaller than is now considered usable, and that within three or four decades the demand for even 50-year-old Douglas fir will be very keen.

## SUMMARY.

A large part of western Washington and Oregon is adapted best to the production of timber, and the forests of this region, consisting largely of Douglas fir, are extremely rapid in growth, and are capable of yielding enormous crops of timber.

The general welfare of the Pacific Northwest demands that the lumber industry be perpetuated and that the potential timberland of these States remain productive of the greatest quantity of the best quality of timber.

Douglas fir is the best timber tree of this region, for it is a tree of extremely rapid growth, great size, valuable wood, vigorous and thrifty development, and of such a character that its forests are easily reproduced without much modification of present logging methods.

Logging in this region has commonly been done in the past without regard for the future of the land cut over, and, in consequence, an unproductive waste has succeeded the original stand of timber.

Logging should be done on all land which is not agricultural in character in such a way that the tree growth will not be annihilated, but so that the forest will be perpetuated, and a second crop take the place of the one removed.

Reforestation can be attained at little expense after any Douglas fir logging operation by the practice of three measures: (1) Making provision for seed trees, to seed up the area; (2) burning the slashing immediately after logging; (3) protecting the cut-over area from subsequent fires.

The observance of these measures will promote the development of a second crop whose growth will be as rapid and whose quality as good as the original forest.

That the growing of crops of Douglas fir on cut-over land will be financially profitable to private owners seems assured in view of the certain rise in the valuation of stumpage, the growing security of timberland investments, and the increased market for young timber, provided only that the system of taxing timberlands is reformed so that such lands bear only their just share of taxation.

# APPENDIX.

Table A shows the average contents in cubic feet of trees of different diameters, for various total heights. This was obtained by measuring the diameter inside the bark every 10 feet throughout the length of the stem, and is therefore a very accurate guide to the total amount of wood in a tree.

Table B shows the merchantable contents in board feet of trees over 12 inches in diameter for various merchantable heights, expressed in 16-foot logs. The trees on which this table was based were all actually scaled by calipering them as 16-foot logs or shorter, 2 inches being allowed at the end of each log and the stump height being considered equal to the diameter of the tree. The trees were considered merchantable up to 8 inches in diameter inside the bark or to a point above which they were unmerchantable because of serious defect such as crook, fork, unavoidable breakage, heavy limbs, or decay. Parts of the main stem which were unmerchantable because of decay, crook, fork, etc., were not scaled, but such defect was so slight that its inclusion would affect the table certainly less than 4 per cent.

Table C shows the number of hewed railroad ties, 8 inches × 6 inches × 8 feet in size, and of linear feet of round mine timber with diameters ranging between 6 inches and 10 inches, obtainable from trees 7 to 19 inches in diameter.

Table A.—*Volume table for Douglas fir, showing diameter at breastheight, total height, and contents (inside bark) of whole stem in cubic feet, read from curves.*

| Diameter at breast-height (inches). | Total height in feet. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| | Volume in cubic feet. | | | | | | | | | | |
| 2 | 0.2 | 0.3 | | | | | | | | | |
| 3 | .6 | .7 | 0.8 | 1 | | | | | | | |
| 4 | 1 | 1.3 | 1.8 | 2.2 | 2.8 | | | | | | |
| 5 | 1.6 | 2 | 2.5 | 3 | 3.6 | 4.4 | | | | | |
| 6 | | 2.7 | 3.3 | 4.1 | 5 | 6.2 | 7.6 | | | | |
| 7 | | 3.7 | 4.6 | 5.6 | 6.7 | 7.8 | 9.1 | 10.5 | 12.2 | | |
| 8 | | | 6.2 | 7.4 | 8.7 | 10.1 | 11.6 | 13.2 | 15 | | |
| 9 | | | 8 | 9.5 | 11.1 | 12.7 | 14.6 | 16.8 | 19.2 | 21.5 | |
| 10 | | | | 12.3 | 14 | 15.8 | 17.8 | 19.9 | 22.4 | 25.8 | 31.6 |
| 11 | | | | 15.2 | 17 | 18.9 | 20.9 | 23.4 | 26.4 | 29.9 | 34 |
| 12 | | | | | 20 | 22.2 | 24.6 | 27.6 | 31.2 | 35 | 39 |
| 13 | | | | | 22.8 | 25.8 | 29 | 32.4 | 36 | 39.8 | 44 |
| 14 | | | | | 25.5 | 29 | 33 | 37 | 40.5 | 44.5 | 49 |
| 15 | | | | | | 35.5 | 39 | 43 | 47.5 | 51.8 | 56.5 |
| 16 | | | | | | 40 | 44.5 | 48.8 | 53.5 | 58.2 | 63.3 |
| 17 | | | | | | 44.8 | 49.5 | 54.5 | 59.5 | 64.8 | 70.3 |
| 18 | | | | | | | | 62 | 67.5 | 72.7 | 78 |
| 19 | | | | | | | | | 75 | 80.5 | 86.5 |
| 20 | | | | | | | | | 83.5 | 89 | 94.5 |
| 21 | | | | | | | | | | 99 | 105 |
| 22 | | | | | | | | | | 118 | 115 |
| 23 | | | | | | | | | | | 123 |
| 24 | | | | | | | | | | | 130 |
| 25 | | | | | | | | | | | 142 |
| 26 | | | | | | | | | | | 155 |

TABLE A.—*Volume table for Douglas fir, showing diameter at breastheight, total height, and contents (inside bark) of whole stem in cubic feet, read from curves*—Continued.

| Diameter at breast-height (inches). | Total height in feet. | | | | | | | | | | Basis, number of trees. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | |
| | Volume in cubic feet. | | | | | | | | | | |
| 2 | | | | | | | | | | | 37 |
| 3 | | | | | | | | | | | 29 |
| 4 | | | | | | | | | | | 91 |
| 5 | | | | | | | | | | | 95 |
| 6 | | | | | | | | | | | 72 |
| 7 | | | | | | | | | | | 82 |
| 8 | | | | | | | | | | | 78 |
| 9 | | | | | | | | | | | 78 |
| 10 | | | | | | | | | | | 80 |
| 11 | | | | | | | | | | | 62 |
| 12 | | | | | | | | | | | 66 |
| 13 | 48.4 | | | | | | | | | | 67 |
| 14 | 54 | 59.5 | 65.5 | | | | | | | | 86 |
| 15 | 61.5 | 67 | 72.5 | | | | | | | | 68 |
| 16 | 68.8 | 74.5 | 80.5 | | | | | | | | 63 |
| 17 | 76 | 82 | 88 | 94 | | | | | | | 54 |
| 18 | 84 | 90 | 97 | 104 | 112 | 120 | | | | | 48 |
| 19 | 92.5 | 99 | 106 | 114 | 122.5 | 131 | | | | | 49 |
| 20 | 101 | 107.5 | 115 | 123 | 131.5 | 140.5 | | | | | 45 |
| 21 | 111.5 | 118.5 | 125.5 | 133 | 142 | 152.5 | | | | | 61 |
| 22 | 121 | 128 | 135 | 144 | 153 | 163 | | | | | 39 |
| 23 | 130 | 138 | 146 | 155 | 165 | 179 | 195 | | | | 40 |
| 24 | 138 | 146 | 155 | 165 | 177 | 192 | 211 | | | | 47 |
| 25 | 150 | 158 | 167 | 176 | 188 | 203 | 224 | 254 | | | 28 |
| 26 | 163 | 171 | 179 | 188.5 | 200 | 216 | 235 | 264 | | | 38 |
| 27 | 175 | 184 | 193 | 204 | 215 | 228 | 246 | 269 | 295 | | 45 |
| 28 | 184 | 193 | 204 | 215 | 228 | 243 | 261 | 283 | 308 | | 21 |
| 29 | | | 217 | 230 | 244 | 259 | 277 | 298 | 321 | 348 | 31 |
| 30 | | | | 249 | 262 | 278 | 296 | 317 | 342 | 370 | 30 |
| 31 | | | | 266 | 278 | 292 | 310 | 332 | 357 | 387 | 24 |
| 32 | | | | 283 | 297 | 310 | 327 | 348 | 373 | 402 | 21 |
| 33 | | | | 307 | 318 | 331 | 348 | 370 | 396 | 424 | 22 |
| 34 | | | | 308 | 339 | 352 | 368 | 388 | 412 | 439 | 19 |
| 35 | | | | 344 | 354 | 367 | 384 | 404 | 431 | 460 | 5 |
| 36 | | | | 363 | 373 | 386 | 404 | 426 | 451 | 480 | 6 |
| 37 | | | | | 394 | 406 | 424 | 447 | 462 | 503 | 4 |
| 38 | | | | | | 426 | 445 | 468 | 496 | 532 | 5 |
| 39 | | | | | | | 472 | 492 | 520 | 560 | 3 |
| 40 | | | | | | | 492 | 514 | 546 | 593 | 1 |
| 41 | | | | | | | | 535 | 569 | 624 | 2 |
| 42 | | | | | | | | 556 | 586 | 634 | 3 |
| 43 | | | | | | | | 576 | 608 | 666 | 0 |
| 44 | | | | | | | | 600 | 637 | 702 | 2 |
| | | | | | | | | | | | 1,747 |

TABLE B.—*Volume table for Douglas fir, showing diameter at breastheight, merchantable length in 16-foot logs, and available merchantable contents in board feet, by the Scribner Decimal C rule, western foot-hills of the Cascade Mountains in Washington and Oregon, read from curves.*

| Diameter at breastheight. | Number of 16-foot logs. | | | | | | | | | | Basis, number of trees. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average volume for all heights. | |
| | Feet, board measure. | | | | | | | | | | |
| *Inches.* | | | | | | | | | | | |
| 12 | 70 | 124 | 177 | ...... | ...... | ...... | ...... | ...... | ...... | 108 | 39 |
| 13 | 112 | 141 | 197 | 260 | ...... | ...... | ...... | ...... | ...... | 140 | 53 |
| 14 | ...... | 158 | 216 | 284 | ...... | ...... | ...... | ...... | ...... | 187 | 80 |
| 15 | ...... | 177 | 237 | 310 | 395 | ...... | ...... | ...... | ...... | 238 | 57 |
| 16 | ...... | 203 | 259 | 336 | 422 | ...... | ...... | ...... | ...... | 300 | 54 |
| 17 | ...... | 236 | 283 | 363 | 447 | 512 | ...... | ...... | ...... | 365 | 53 |
| 18 | ...... | ...... | 308 | 391 | 477 | 567 | ...... | ...... | ...... | 435 | 47 |
| 19 | ...... | ...... | 336 | 420 | 512 | 623 | 708 | ...... | ...... | 510 | 47 |
| 20 | ...... | ...... | 364 | 452 | 555 | 678 | 778 | ...... | ...... | 595 | 34 |
| 21 | ...... | ...... | 394 | 485 | 600 | 735 | 854 | 975 | ...... | 680 | 61 |
| 22 | ...... | ...... | ...... | 520 | 650 | 797 | 930 | 1,080 | ...... | 775 | 40 |
| 23 | ...... | ...... | ...... | 559 | 705 | 862 | 1,012 | 1,185 | ...... | 870 | 40 |
| 24 | ...... | ...... | ...... | 601 | 765 | 930 | 1,095 | 1,290 | 1,515 | 970 | 45 |
| 25 | ...... | ...... | ...... | 644 | 835 | 1,008 | 1,130 | 1,390 | 1,612 | 1,080 | 29 |
| 26 | ...... | ...... | ...... | 696 | 915 | 1,090 | 1,271 | 1,487 | 1,713 | 1,195 | 38 |
| 27 | ...... | ...... | ...... | 780 | 1,004 | 1,180 | 1,365 | 1,585 | 1,818 | 1,320 | 45 |
| 28 | ...... | ...... | ...... | ...... | 1,101 | 1,280 | 1,462 | 1,685 | 1,932 | 1,450 | 24 |
| 29 | ...... | ...... | ...... | ...... | 1,203 | 1,385 | 1,570 | 1,790 | 2,058 | 1,595 | 32 |
| 30 | ...... | ...... | ...... | ...... | 1,314 | 1,495 | 1,685 | 1,900 | 2,185 | 1,745 | 30 |
| 31 | ...... | ...... | ...... | ...... | 1,440 | 1,600 | 1,815 | 2,020 | 2,315 | 1,900 | 23 |
| 32 | ...... | ...... | ...... | ...... | 1,570 | 1,730 | 1,950 | 2,145 | 2,470 | 2,065 | 22 |
| 33 | ...... | ...... | ...... | ...... | 1,695 | 1,870 | 2,100 | 2,300 | 2,630 | 2,235 | 22 |
| 34 | ...... | ...... | ...... | ...... | 1,815 | 2,005 | 2,245 | 2,470 | 2,810 | 2,415 | 16 |
| 35 | ...... | ...... | ...... | ...... | 1,940 | 2,140 | 2,385 | 2,650 | 3,000 | 2,600 | 5 |
| 36 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2,795 | 9 |
| 37 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2,990 | 6 |
| 38 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3,180 | 5 |
| 39 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3,360 | 3 |
| 40 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3,530 | 1 |
| 41 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3,680 | 2 |
| 42 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3,830 | 3 |
| 43 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3,975 | 0 |
| 44 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 4,115 | 2 |
| 45 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 4,250 | 0 |
| 46 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 4,385 | 0 |
| | | | | | | | | | | | 967 |

TABLE C.—*Number of standard railroad ties and amount of mining timber, in linear feet, obtainable from trees of various diameters.*

| Diameter at breastheight. | Railroad ties. | Mining timber. | Basis. |
|---|---|---|---|
| *Inches.* | *No.* | *Lin. ft.* | *No. of trees.* |
| 7 | ...... | 25.2 | 12 |
| 8 | ...... | 32.8 | 58 |
| 9 | ...... | 35.1 | 107 |
| 10 | ...... | 40.9 | 106 |
| 11 | 0.1 | 46.4 | 56 |
| 12 | 1.4 | 44.7 | 49 |
| 13 | 3.0 | 38.5 | 53 |
| 14 | 4.6 | 34.7 | 64 |
| 15 | 5.4 | 29.5 | 51 |
| 16 | 6.7 | 26.8 | 36 |
| 17 | 7.3 | 23.6 | 20 |
| 18 | 7.8 | 21.1 | 9 |
| 19 | 7.9 | 20.0 | 12 |
| | | | 633 |

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